Solenoids and Magnetic Focusing

Cornell ERL Phase 1B Gun: *External Review*, 1/5/11

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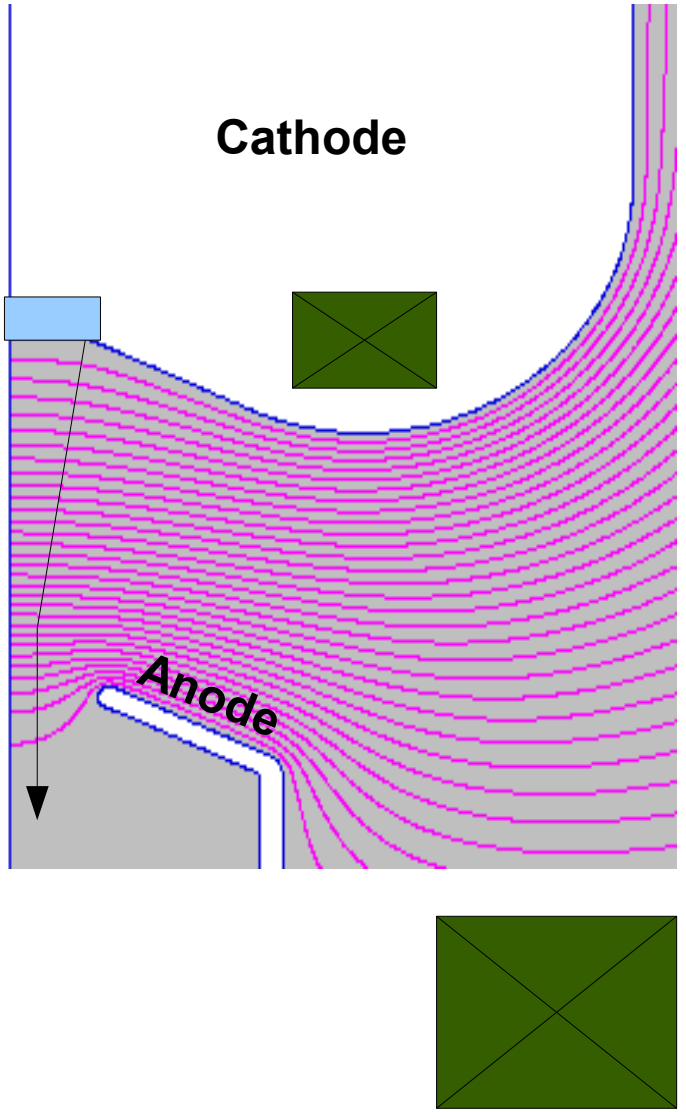
Magnetic Focusing

- Let's entertain the possibility of using magnetic focusing in the gun.
- Embed a pair of solenoids within the gun assembly.
  - Must be a pair to guarantee B=0 at p.c. surface.
  - Else, in magnetic field:

$$H(x,p) \rightarrow H(x,p-\frac{e}{c}A)$$

  - Adds angular momentum term to thermal emittance.



Requirements

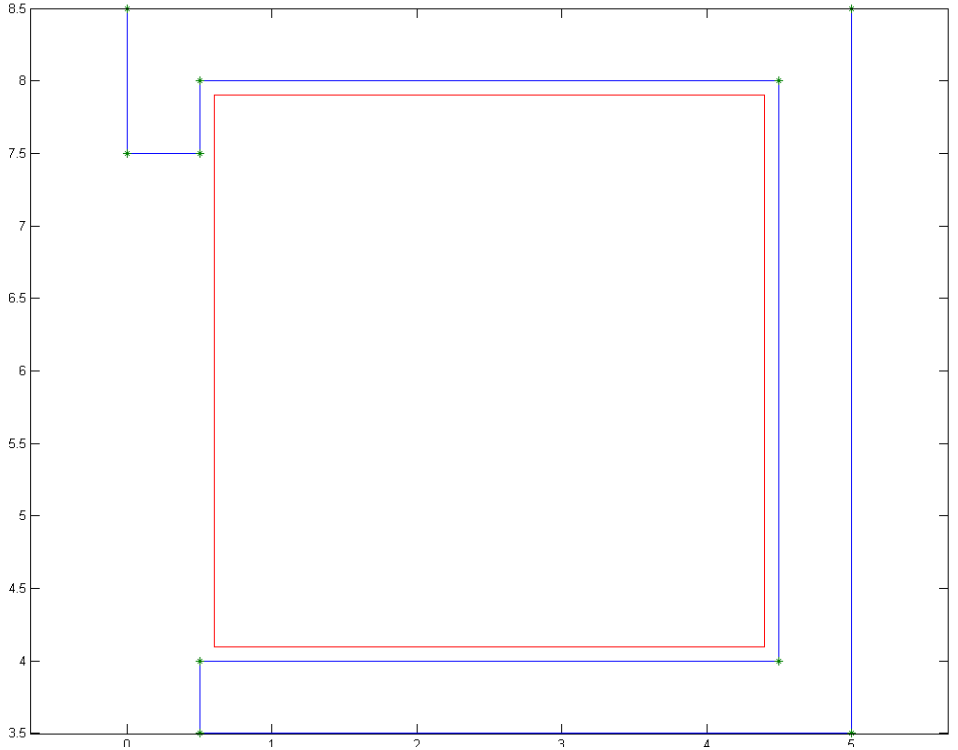
- Must be able to provide significant focal length, while fitting inside the assembly.

$$\frac{1}{f_m} = \left(\frac{e}{2m_e c\gamma\beta}\right)^2 \int B^2 dz$$

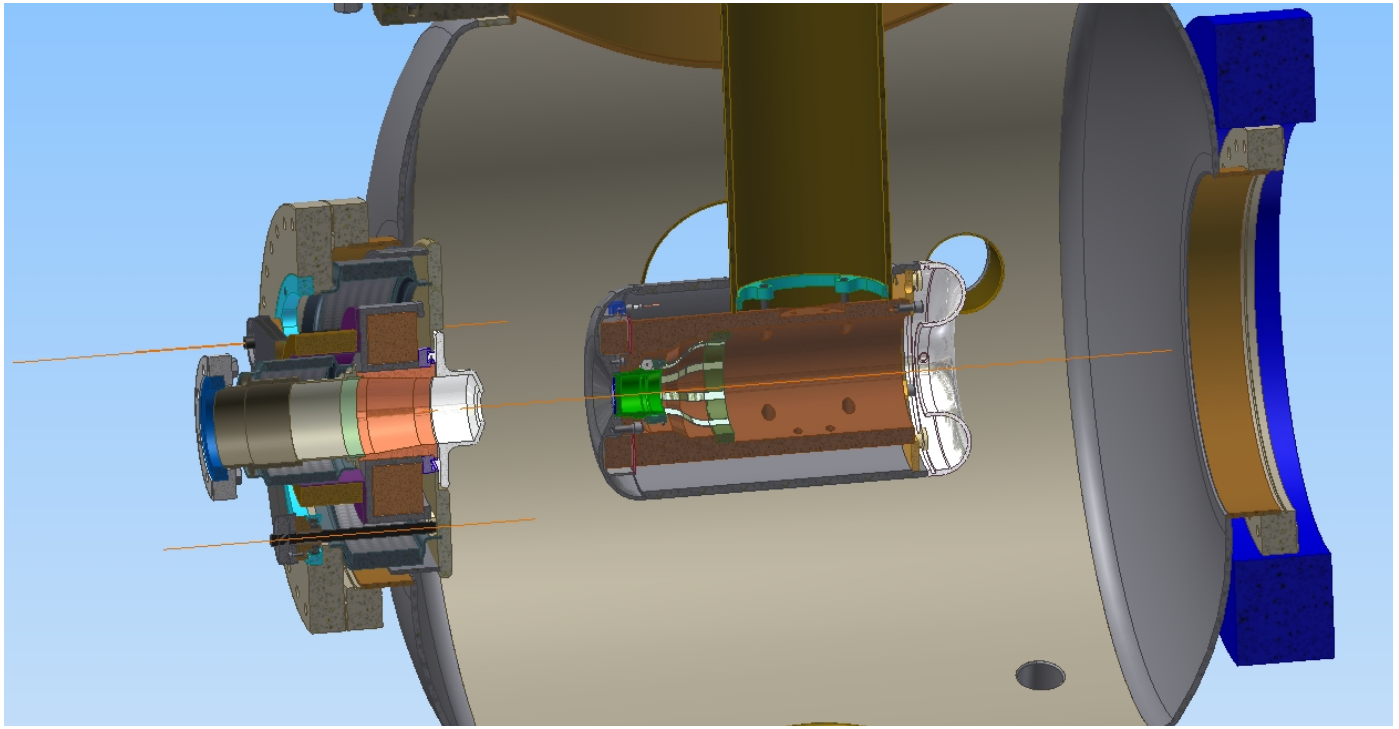
- Focusing provided by the anode solenoid
  - Want it as close as possible; include in anode assembly. Restricts size.
  - Can include iron.
- Want bucking solenoid to be strong at p.c. surface, weak elsewhere.

Anode Coil

- Limited to a package of around 50x50 square mm.
- Design the yoke arms to enhance cathode field.



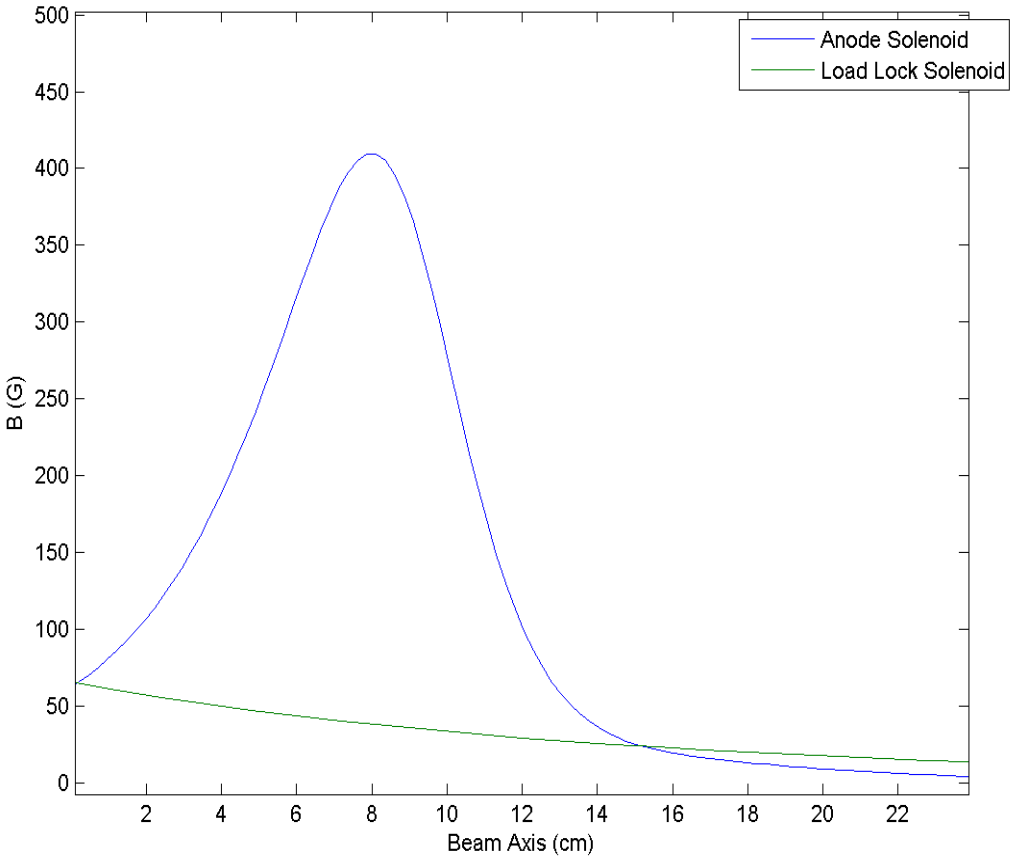
Bucking Coil



- Two options:
  - 1) Place externally, behind gun assembly.
  - 2) Place within cathode electrode.
    - Must be driven at HV, no iron, small radius.

External Bucking coil

- External Design:
  - Will be large radius—field has large tail.
  - Must provide 50-70 G at p.c. surface
  - Can include iron yoke, similar to anode design.
  - What must the dimensions be?

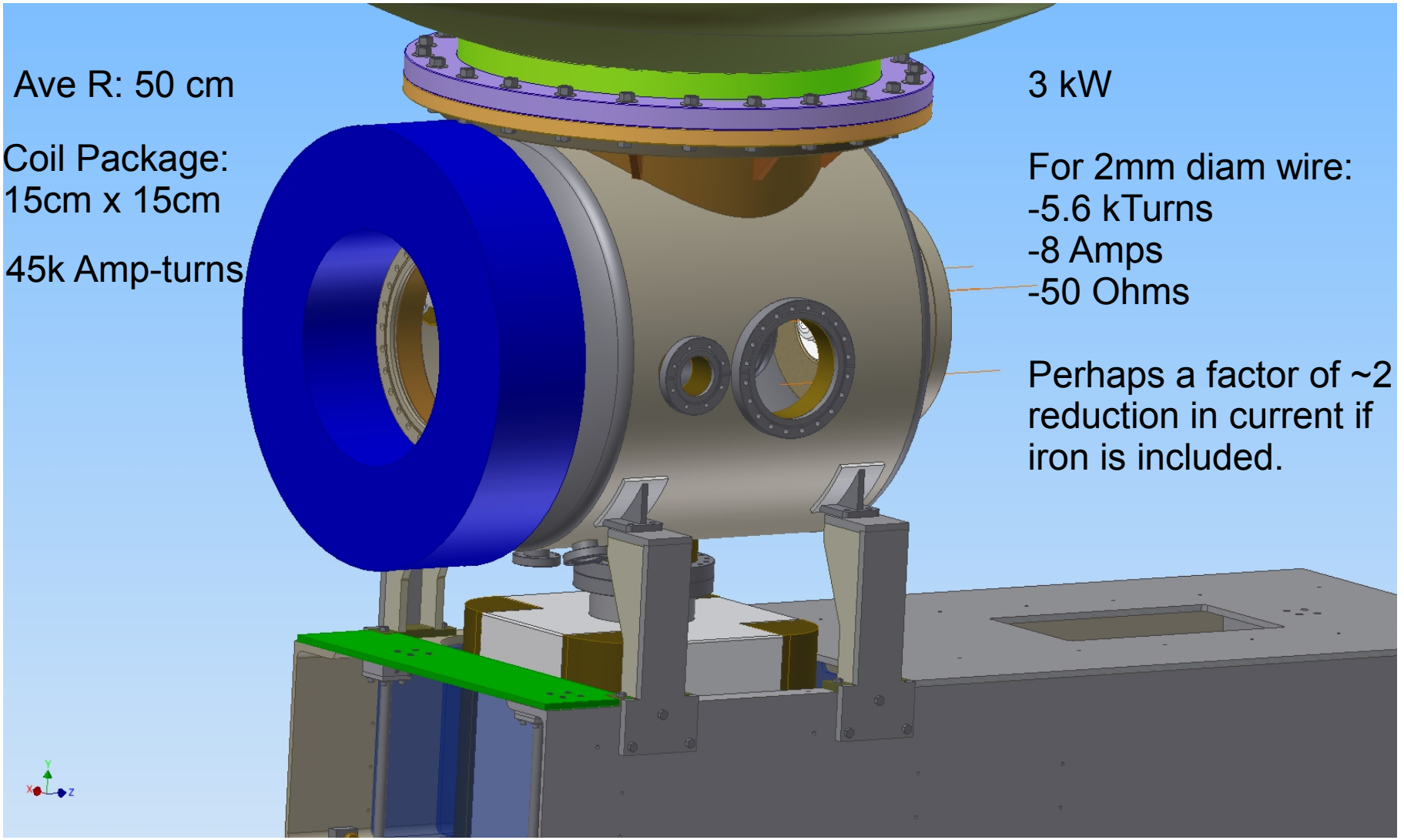


External Bucking Coil

Ave R: 50 cm

Coil Package:
15cm x 15cm

45k Amp-turns

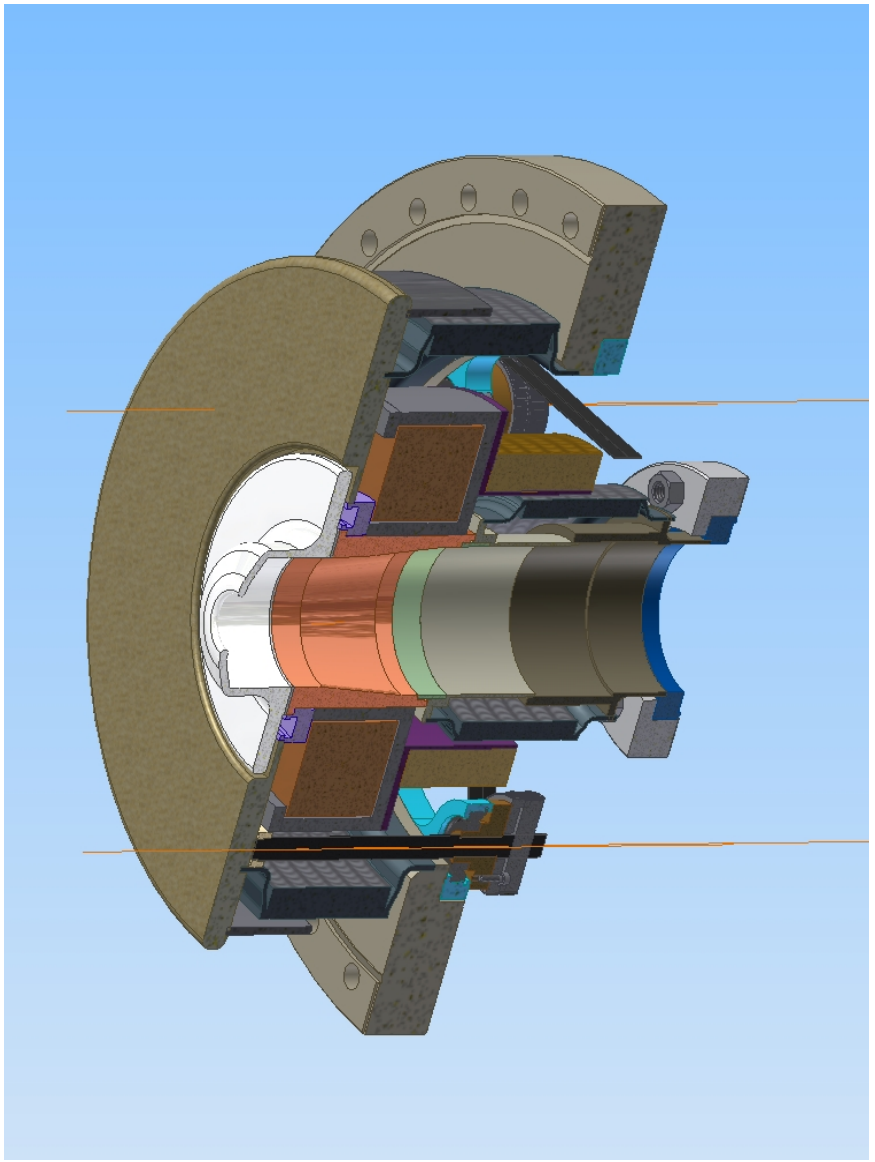


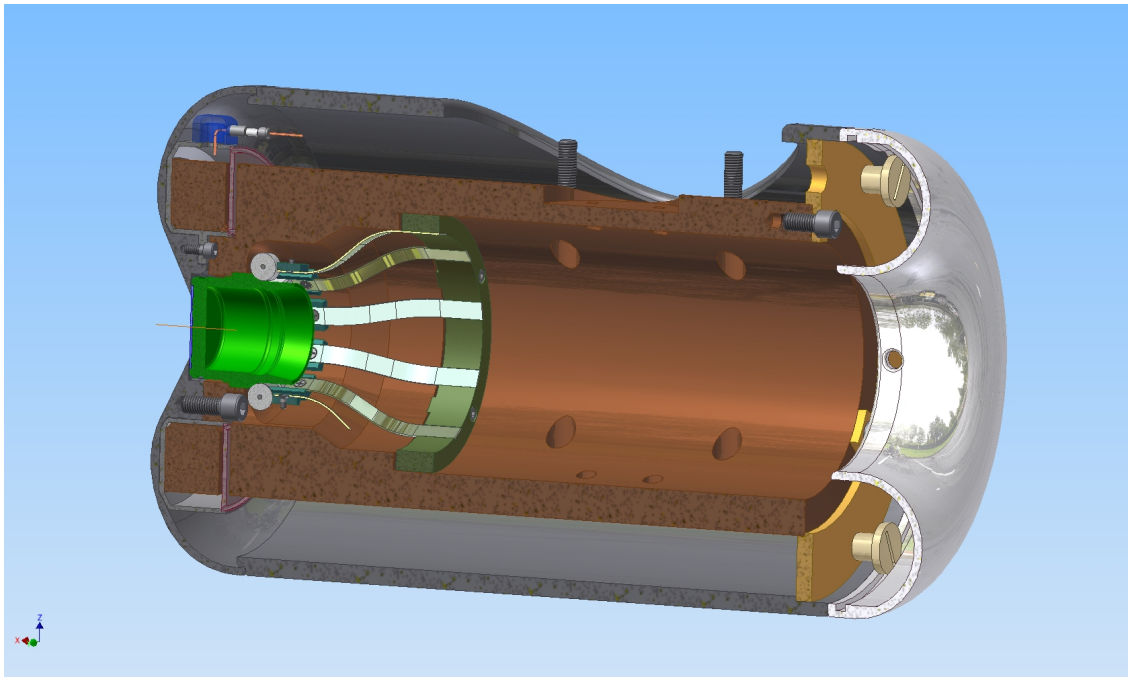
3 kW

For 2mm diam wire:
-5.6 kTurns
-8 Amps
-50 Ohms

Perhaps a factor of ~2 reduction in current if iron is included.

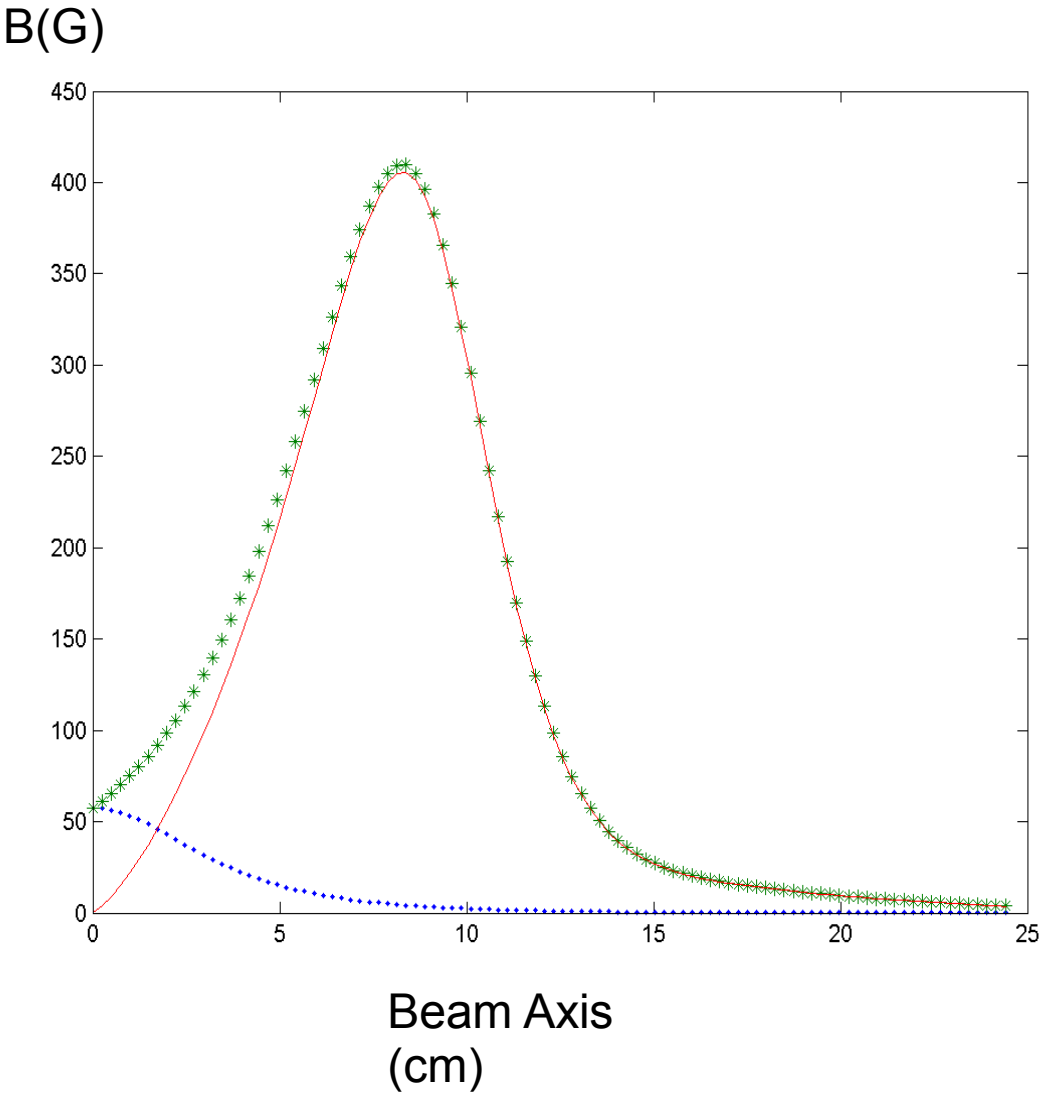
Close Ups: Coil Packages





Internal Solenoid &Focusing

- Assume maximum of $2\mathrm{A/mm}^2$
  - Field profile shown
- Gives $f_m = 0.4\mathrm{m}$
  - $f_e = 0.2\mathrm{m}$
- Expect significant effect on emittance.
- External coil has ~10% reduction.



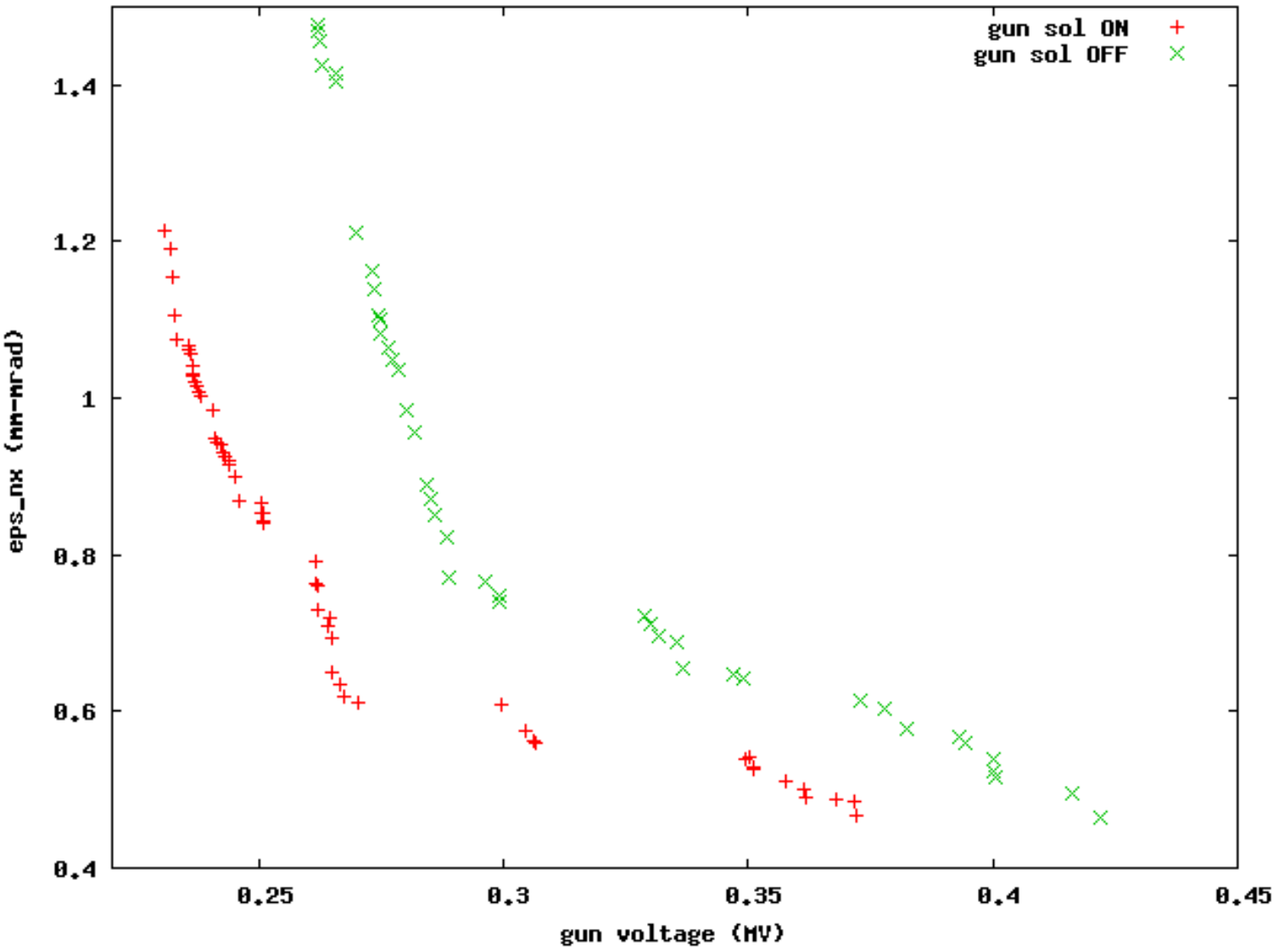
Internal Solenoid

- At a gap of 50mm, bucking coil well below max current capacity.
  - <20 W power to dissipate
- Decreasing gap does not necessarily decrease f
  - Increases effect of bucking coil tail.
  - Could be up to 60W dissipated in cathode.
- Good cancellation at photocathode surface
  - Bz less than 2 G for 5mm radial offset.

Effect on Emittance

- Emittance reduction is our ultimate goal
- Simulate using Astra
- Includes “short beamline” optimization including:
  - Fixed gap, fixed angle (small).
  - Varied gun voltage
  - Varied downstream solenoid currents
- What kind of gains do we expect?
- Can we skip electrostatic focusing?

Optimization Results



Optimization Results

- Particular parameterization? Coming talk.
- Significant effect on emittance, as we expect
  - 30% reduction in emittance, or 1kV less.
- Probably can't get rid of electrostatic focusing.
- Defer to Karl for:
  - Mechanical details,
  - Far prettier pictures

Conclusions

- Magnetic focusing on this scale can have significant effect on emittance.
- Two viable solenoid options:
  - External solenoid must be quite large, but still feasible.
  - While slightly better field profile, the internal solenoid poses a large number of technical difficulties.